Soil Chemical and Physical Characteristic and Rice Yield under Three Farming Systems in Sragen District, Central Java Province

Karakteristik Sifat Kimia dan Fisika Tanah dan Produksi Brangkasan Padi pada Tiga Sistem Budidaya di Kabupaten Sragen, Propinsi Jawa Tengah

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Abstract. The farmers want to move from green revolution technology to other rice systems because the former is no longer sustainable.The aim of this study was to study soil chemical-physical characteristics and rice productions of three different rice farming systems. This study was carried out in Sambiredjo Sub District, Sragen Regency, arranged in randomized complete block design with three replications and as the treatments was an organic, semi organic and conventional rice system. One kilo gram composites soil samples of 0-20 cm in depth were collected from five random sampling points of every site and taken in March 2017, before soil preparation. Rice biomass productions namely rice grains, rice straw and rice residues were harvested in the end of June 2017.The results indicated that in organic field, the soil chemical-physical fertility was superior to that of in semi organic and conventional and semi organic system was better than conventional in terms of soil pH, organic C and total N, P and K total, soil bulk density, particle density, soil porosity and permeability. Similar finding was observed for rice biomass productions. The rice grains yields were 7.52±0.49, 6.40± 0.10 and 6.07±0.38, rice straw were 9.04±0.61, 8.67±0.58 and 6.87±0.72 and for rice residues were 4.82±0.48, 3.25±0.31 and 3.23±0.35 tons ha^{-1} $season^{-1}$ for organic, semi organic and conventional systems, respectively. Compared to the conventional system, the organic increased about 23 %, 31% and 49 % for rice grains, rice straw and rice residues, respectively. Comparing conventional to semi organic, the improvement was 5 %, 26 % and 0.62 % for rice grains, rice straw and rice residues, respectively. This short term research concluded that organic rice farming was superior than both semi organic and conventional systems, but the long term effect need to be further evaluated.

Abstrak. Sebagian petani ingin beralih ke budidaya padi organik karena teknologi *green revolution* yang mengandalkan masukan tinggi dipandang tidak lumintu. Penelitian bertujuan untuk mempelajari sifat fisik dan kimia tanah serta mengetahui hasil padi dari sistem organik, semi organik dan konvensional. Penelitian dilaksanakan di Kecamatan Sambiredjo, Kabupaten Sragen dengan menggunakan rancangan acak kelompok yang diulang tiga kali, dengan perlakuan: budidaya padi organik, semi organik dan konvensional. Sebanyak satu kilo gram contoh tanah komposit dari ketiga sistem pada kedalaman 0-20 cm diambil dari lima titik secara acak, masing-masing sebelum pengolahan tanah pada bulan Maret 2017. Panen brangkasan padi, yang meliputi gabah, jerami dan sisa tanaman (akar dan potongan batang yang tertinggal) dilakukan pada akhir bulan Juni 2017. Hasil percobaan menunjukkan bahwa sifat kimia dan fisik tanah pada sistem organik lebih unggul dibandingkan dengan semi organik dan konvensional meliputi pH tanah, C organic, kandungan N, P dan K total, berat jenis, kepadatan partikel, porositas dan permeabilitas tanah. Selain itu, budidaya semi organik lebih baik dibandingkan dengan konvensional.Hasil gabah kering dari masing masing teknologi tersebut adalah 7,52±0,49; 6,40±0,10 dan 6,07±0,38, jerami sebesar 9,04±0,61, 8,67±0,58 dan 6,87±0,72 dan sisa tanaman seberat 4,82±0,48; 3,25±0,31 dan 3,23±0,35 ton $ha^{-1}musim^{-1}$pada budidaya padi organik, semi organik dan konvensional. Dibandingkan dengan budidaya konvensional, sistem organik meningkatkan gabah, jerami dan sisa tanaman berturut turut sebesar sebesar 23 %, 31 % dan 49 %. Apabila dibandingkan antara sistem konvensional dengan semi organik, juga terjadi peningkatan sebesar 5 %, 26 % dan 0.62 % untuk gabah, jerami dan sisa tanaman. Penelitian ini menyimpulkan bahwa budidaya padi organik lebih unggul dibandingkan dengan semi organik dan konvensional namun pengaruh jangka Panjang perlu dievaluasi lebih lanjut.

Introduction

It is coming to realize that green revolution technology with high rate mineral fertilizers and synthetics pesticides are no longer sustainable. Most farmers want to move to other rice farming systems. Some farmers want to change to organic rice farming technology, some of them to semi organic and the rests still do conventional rice farming systems with some improvements (Sukristiyonubowo *et al*. 2016).

Recently, both in organic rice and vegetables farming systems have become more up-to-date responding to environmental problems particularly in developing country that has declared significant effects in agriculture land

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degradations, healthy food and farmer's income. Furthermore, organic farming has become a model to sustain the agricultural products, improve farmers' income and environmental degradation (Sukristiyonubowo *et al.* 2011). Hence, in modern agriculture systems, recently the organic farmings (rice, vegetables or fruits) are chosen by the farmers because of some advantages. Not only solve the environment degradations and agronomic problems, but also gives some benefits in term of socio economic aspects.

In some countries, research in organic farming system have been developed both in plot, farm and community scales with different purposes. Some advantages of organic rice farming are reported by researchers. Chino *et al*. (1987) found that in the organic cultivation, the asparagine's content of plant phloem sap is significantly lower than in conventional systems. Kajimura *et al*. (1995) reported that the low densities of B*rown Plant Hopper* and White Backed Plant Hopper are observed in organic fields. Similar finding was reported by Alice *et al.* (2004). Furthermore, Prakhas *et al.* (2002) noted that rice planted in organic technology has better inmilling and cooking quality like total and head milled rice recovery, protein content, kernel elongation and lower in amylose content than cultivated inconventional system with commercials fertilizers and pesticides. Zhang and Shao (1999) reported that higher protein grains content will result in higher head rice recovery and lower amylose content. In line with the soil, organic farming is usually associated with a significant higher level of biological activities and soil organic matter than in green revolution technology (Oehl *et al*. 2004; Mader *et al.* 2002; Hansen *et al*. 2000; Stolze *et al.* 2002). In fact, there are still limited studies on comparing organic versus conventional systems (Hasegawa *et al*. 2005).

In Indonesia, the organic foods markets (rice, vegetables and fruits) are tremendously increasing due to growing demand for rice, vegetables and fruits of organics and their high premium obtained, besides the consumers need healthy foods and free from chemical, for example IR 64 and Mentik Wangi varieties are planted in organic rice farming system in Sragen District because of have high selling price, good taste and have many advantages.

In the past, during application of the green revolution technology, combination between high external input and high yielding variety are promising way to elevate rice yields (Sukristiyonubowo and Tuherkih 2009; Zhang and Wang 2005; Min *et al.* 2003; Cho *et al.* 2002; 2000; Soepartini 1995; Adiningsih 1992; Adiningsih *et al.* 1989; Prawirasumantri *et al.* 1983; Cooke 1970; Uexkull 1970). In vegetables growing areas, the application of inorganic fertilizers are also very significant, for instance the use of N fertilizers in leafy vegetables, K in tuber crops both are very high. However, this technology is considered not sustainable for the long term (Yan *et al.* 2007). In conventional rice growing centres are showing a levelling-off, even a decline or loss in productivity. Now in Indonesia, there are organic faming and conventional systems both for rice and vegetables. The yield of rice and vegetables of organic farming is better than conventional system. The objective this research was to study soil chemical-physical characteristics and rice yield under three farming systems in Sambiredjo Sub District, Sragen District. Central Java Province.

Methodology

The study was carried out in three rice farming systemsat Sambirejo Sub District of Sragen Regency, Central Java Province namely organic, semi organic and conventional rice farming systems. These rice farming technologies were used as the treatments. The farmers conducted organic and semiorganic rice farming system since 2000 and 2004, respectively. In semi organic, the farmers still apply nitrogen fertilizer as much as 50 kg and rock phosphate 50 kg ha^{-1} $season^{-1}$ at planting time, while in organic rice farming they only apply organic fertilizer (straw compost) as much as 3-4 tons ha^{-1} every cropping season. In conventional rice farmings, they usually apply organic fertilizer (about 1 ton ha^{-1} $season^{-1}$ straw compost) and mineral fertilizer as much as 200 kg ha^{-1}urea, 150 kgha^{-1}PONSKHA (15:15:15) and 50 kg KCl ha^{-1} $season^{-1}$.

The composite soil of 0-20 cm in depth were sampled in March 2017, before soil preparation.One kg soil composite was collected from five sampling points of every site and mixed. These samples were submitted to the Soil Analytical Laboratory of the Jogyakarta Assessment Institute for Agricultural Technology for analyses of chemical and physical parameters of the soils. Chemical analyses included the measurement of pH (H_20 and KCl), organic matter, phosphorus, and potassium. Organic matter was determined using the Walkley and Black method, pH (H_2O and KCl) was measured in a 1:5 soil-water suspension using a glass electrode, total P and soluble P were measured colorimetrically, extracted using HCl 25% and Olsen methods, respectively. The total K was extracted using HCl 25% and subsequently determined by flame-spectrometry (Soil Research Institute 2009). Physical analyses included the measurement of water level, particle density (PD), bulk density (BD) and total pore space. Water level was measured by Gravimetric method, particle density was measured using Richards and Fireman method (1943), bulk density was measured by Richards method (1947) and total pores space was measured using De Boodt method (1967). All measurement of physical properties adopted from Indonesian Soil Research Institute (2009).

IR-64 rice variety was cultivated as plant indicator. Transplanting was carried out in the middleof March 2017 and harvest in the end of June 2017. Twenty-one-day old seedlings were transplanted at about 25 cm x 25 cm cropping distance with about three seedlings per hill.

Rice biomass production including rice grains, straw, and residues were measured at harvest. When water content in rice grains were 16 %, the rice plants was harvested, and for measurement the constant weight of rice grains yield, the water content of 14 % was used. Sampling units (1m x 1 m plot), were randomly selected at every rice systems. Rice plants were manually cut about 20 cm above the ground surface. The samples were manually separated into rice grains, rice straw, and rice residues. Rice residues included the roots and the part of the stem (stubble) left after cutting. Fresh weights of rice grain, rice straw, and rice residues were immediately weighed at harvest at each sampling unit. Rice productions were statistically analysed in Random Complete Block Design (RCBD). All data were statistically examined and computed using SPSS software. Means were compared using the Duncan test (5%).

Results and Discussion

Soil Fertility Properties

The soil fertilities discussed were only soil chemical and physical parameters.The soil chemical data are presented in Table 1.

In general, when it compared to the original soil taken in 2008, the soil chemical fertilities in 2017 including soil pH, C-organic (%), N total (%), P and K extracted with 25 % HCl were tremendously improved, because of continuously addition of straw compost. The soil pH improved from 5.80 became 6.00 to 6.90, the soil organic carbon increased from 1.21% became 1.30 to 3.80 % and N total in the soil improved from 0.11 became 0.17 to 0.28 % and P extracted with 25 % HCl increased from 16.05 became 41.70 to 62.30 mg 100 gr^{-1}, as well as K extracted with HCl increased from 7.90 became 19.70 to 37 mg 100 gr^{-1} (Table 1.)

In the year 2017, the pH of the soil in organic rice field was 6.90 and classified as neutral, but in the semi organic and the conventional rice farming practices tend to slightly acid. The neutral of the soil in organic rice field may be due to continue applying organic manures. Moreover, the neutral of soils may be due to accumulations of organic acids like fulvic and humic acids released by organic materials (compost and manure) added by the farmers. In contras, in the semi organic and conventional systems, the soil pH was about 6.60 and 6.00, respectively. These acidity of soils may be due to accumulations of mineral fertilizer (urea) appliedby the farmers. The level of soil organic carbon (SOC) and total N was classified as high in the organic rice farming system,but both inthe semi organic was classified as medium and in the conventional rice farming systems was considered as low. Furthermore, it can be concluded that in organic rice farming system, the soil organic carbon (SOC) and total N was considered as the highest, 3,8 % for soil organic carbon and 0,28 % for the N total, and the lowest was atthe conventional rice field about 1.3 % for soil organic carbon and 0.17 % forthe total N. According to Sommerfeldt *et al.* (1988) and Clark *et al.* (1998) they reported that the higher soil organic matter (SOM) levels find in the soils managed with manure and cover crops than in soils without such inputs. For the conventional rice farming system, the total P or potential P extracted with HCl 25% classified as medium, and thiswas lower thanin rice organic and semi organic rice cultivation systems, suggesting that application of organic fertilizers about 3 – 4 tons compost ha^{-1} $season^{-1}$ and rock phosphate as much as 50 kg ha^{-1} $season^{-1}$ in semi

Table 1. The soil chemical properties of three rice farming systems in Sambiredjo Sub district, Sragen district, Central Jave Province

Tabel 1. Sifat kimia tanah dari ke tiga sistem budidaya padi, di Kecamatan Sambiredjo, Kabupaten Sragen, Propinsi Jawa Tengah

Treatments	pH_{H2O}	C-organic	N-total	P-total (25% HCl)	K2O (25% HCl)
		%		*mg /100g*	*mg /100g*
Original Soil*)	5.80	1.21	0.11	16.05	7.90
Organic rice farming system	6.90	3.80	0.28	62.30	37.70
Semi organic rice farming system	6.60	2.70	0.25	48.90	32.30
Conventional rice farming system	6.00	1.30	0.17	41.70	19.70

Note: *) Original soil taken in 2008 in Sukristiyonubowo *et al*. (2011)

organic were more superior than application of mineral fertilizer(150 kg ha^{-1} season^{-1}PONSKHA) in conventional fields.Thus, it can be said that the total P or potential P extracted with HCl 25% in the conventional rice farming system was the lowest compared to the organic and semi organic rice farmings, because of P fixation (became Al-P, Fe-P or Mn-P due to the lower pH in conventional rice system (pH$_{H20}$: 6.0).

Total K in the organic rice farming system was about 37.7 mg 100 g^{-1} and classified as the highest, followed by the semi organic about 32.3 mg 100 g^{-1}and conventional farming systems about 19.7 mg 100 g^{-1}, indicating that application about 3-4 t ha^{-1} season^{-1} straw compost was enough to increase the total K in the soil. It was also suggesting that straw compost applied in the organic rice farming was rich in K content. Whereas, the totalK in the soil ofthe conventional rice farming system was considered low indicating addition of about 50 kg KCl ha^{-1} season $^{-1}$ cannot increase the total K in the soil. Clark *et al.* (1998); Rasmussen and Parton (1994) and Wander *et al.* (1994) also reported similar observations. Therefore, it may be concluded that soil fertilityin the rice organic farming in general were better than in semi organic and conventional rice farming systems including the pH,organic matter content (nitrogen content) and P and K concentrations. In addition, in theconventional rice farming applications of proper mineral fertilizers to improve inherent soil fertility leading to rice yield is needed. Furthermore, the importance of organic sources including compost, straw, and leguminous green manure crops in improving soil chemical and physical properties have also received more attention in recent times (Clark *et al.* 1998; Hasegawa *et al.* 2005; Landa *et al.* 1992; Mandal *et al.* 2003; Ray and Gupta 2001; Whitbread *et al.* 2000; Xu *et al*. 2006).

Soil Physical Properties

The soil physical parameters are presented in Table 2. The texture of the soil were silty clay loam in rice organic and semi organic farmings, and in the rice conventional was clay.The texture did not change compared to soil taken in year 2008 (Sukristiyonubowo *et al*. 2011). According to the soil physical analysis sampled in 2017 showed that in the organic rice field, physical soil properties including bulk density, particle density, soil porosity and permeability were better than in the conventional rice field. In rice organic cultivation, the bulk density was 0.94 gr cm^{-3} compared to conventional rice field was 1.21 gr cm^{-3}, the particle density in the organicsoil was 2.42 gr cm^{-3} and in conventional rice was 2.59 gr cm^{-3}, the soil porosity in organic was 69 % and in conventional system was 50 % and the permeability inorganic rice farming was 2 x 10$^{-3\ cm}$ second^{-1} and conventinal rice was 9.4 x $^{10-4\ cm}$ second^{-1}. The semi organic rice farming system was slightly different with the organic rice farming system, but it was still better than conventional system. This can be happened, because soil organic matter could arrange aggregates incorporated each other and physically becoming stabilized within macroaggregates.

Hence the soil was more porous and total soil porosity was higher compare to the soil structure in the conventional rice. According to Pirngadi (2009) the organic matter applied to the rice fields can elevate the water holding capacity, improve the soil structure to be crumbly, prevent the soil agregates become more slowly. In addition, the soil with enough soil C content can easily improve soil tillage and usually more porous compared to the convcentional rice farming system, which usually has lower C organic content and use inorganic fertilizer. Furthermore, Mandal *et al.* (2003) reported that application of green manure (*Sesbania rostrata*, *Sesbania aculeata*, and *Vigna radiata*) together with different rates of nitrogen fertilizer application increased the concentration of soil organic matter and total nitrogen, improved total pore space, water stable aggregates, hydraulic conductivity, and reduced bulk density.

Table 2. The physical soil properties in three rice farming system at Sragen Regency

Tabel 2. Sifat fisika tanah dari ketiga sistem budi daya padi di Kecamatan Sambiredjo, Kabupaten Sragen.

Treatments	Soil Texture *sand dust clay*	Bulk density	Particle density	Soil porosity	Permeability
	%	gr cm^{-3}	gr cm^{-3}	%	cm second^{-1}
Organic ricefarming	29 36 35	0.94	2.42	68.7	2.3 x 10^{-3}
Semi organic rice farming	27 35 38	1.10	2.51	55.4	8.9 x 10^{-3}
Conventionalrice farming	28 31 41	1.21	2.59	50.2	9.4 x 10^{-4}

Rice Biomass Production

The rice biomass productions of three farming systems are presented in Table 3. The organic rice farming system showed the highest rice biomass productions and significantly different with semi organic and conventional practices, namely rice grains, rice straw, and rice residues productions (Table 3). The superiority of biomass yield in organic rice farming may be due to soil physical and chemical in organic fields were better than in semi organic and conventional rice farming systems. The rice biomass yields were about 7.52 ± 0.49; 9.04 ± 0.61 and 4.82 ± 0.48 tons ha^{-1} $season^{-1}$ for rice grains, rice straw, and rice residues, respectively. Compared to the conventional rice farming system, the organic farming increased about 1.45, 2.16, 1.59 tons ha^{-1} $season^{-1}$ or 23, 31 and 49 % for rice grains, rice straw and rice residues, respectively. In addition, if we compared the conventional rice farming to the semi organic, the improvement was 0.33, 1.80 and 0.02 tons ha^{-1} $season^{-1}$ for rice grain, rice straw and rice residues, respectively.

Table 3. Rice biomass production of differentrice farming systems at Sambiredjo Sub District of Sragen Regency, Central Java Province

Tabel 3. Produksi brangkasan padi dari ketiga sistem budidaya padi di Kecamatan Sambiredjo, Kabupaten Sragen, Propinsi Jawa Tengah

Treatments	Rice Biomas Productions		
	Rice Grains	Rice Straws	Rice residues
	------------- t ha^{-1} $season^{-1}$ -------------		
Organic rice farming system	7.52 ± 0.49 a	9.03 ±0.61 a	4.82 ±0.48 a
Semi organic rice farming system	6.40 ± 0.10 b	8.67 ±0.58 a	3.25 ±0.31 b
Conventional rice farming system	6.07 ± 0.38 b	6.87 ±0.72 b	3.23 ±0.35 b

Conclusion

From the data and discussion, it can be concluded that the soil chemical-physical fertility in organic field in Sambiredjo Sub District, Sragen Regency, was more superior than both in semi organic and conventional and in semi organic was better than in conventional system in terms of soil pH, organic C and N, P and K total, bulk density, particle density, soil porosity and permeability. The similar finding was also observed in rice biomass production. Future research question is how long the organic farming system without external input sustains the production and soil fertility.

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